

### **REMARKS**

The Office Action of April 16, 2009 has been received and carefully reviewed. It is submitted that, by this Response, all bases of rejection are traversed and overcome. Upon entry of this Response, claims 1-20, 48, 49 and 68-72 remain in the application. Claims 5 and 7-11 have been withdrawn. Reconsideration of the claims is respectfully requested.

### ***Withdrawn Claims***

Applicants respectfully submit that claim 1 is an allowable generic claim, and that claims 5 and 7-11 (directed to a withdrawn species) should be considered allowable. As such, it is submitted that currently withdrawn claims 5 and 7-11 are entitled to consideration.

### ***Rejections under 35 U.S.C. § 103(a)***

Claims 1-4, 6, 12, 15-20, 48, 49 and 68-71 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Seabaugh et al. (U.S. Patent Application Publication No. 2003/0027033) in view of Zhou et al. (U.S. Patent Application Publication No. 2003/0180472). The Examiner states that Seabaugh discloses a solid oxide fuel cell including a ceramic electrode upon an electrolyte substrate. The ceramic electrode includes a mixture of two or more components including ionically conducting ceramic electrolyte material and an electrode material powder. The Examiner admits that Seabaugh does not disclose a patterned film including insoluble matter of an imaged photoresist having a plurality of nanowires dispersed therein. The Examiner relies upon the teachings of Zhou to supply this deficiency. The Examiner particularly sets forth that Zhou discloses making a patterned substrate by spin-coating a photo-resist on a substrate, and then submersing the substrate into a solution of nano-objects and water. The Examiner concludes that when the water evaporates, the nano-objects, *or insoluble material* of the photoresist, are present.

At the outset, the Applicants respectfully disagree with the Examiner in her conclusion that the "term 'imaged photoresist' describes a process in which a patterned film is formed on a substrate" and thus is a product-by process limitation that is not given patentable weight.

A photoresist is a polymeric coating that is designed to change properties upon exposure to light (see, e.g., Exhibit A filed herewith; Exhibit A is an online handout for Chemistry 421 at the University of Rochester, the home page for the Chem 421 class was last updated December 18, 2002). Depending upon whether a positive or negative photoresist is used, the photoresist becomes more or less soluble. As shown in Exhibit A, after being imaged (i.e., exposed to light), the less soluble portion (i.e., the insoluble matter) of the photoresist remains. As also shown in Exhibit A (see page 5 of 10), when a negative photoresist is used, the remaining photoresist is the original polymer having less solubility than it did prior to such exposure, and when a positive photoresist is used, the remaining photoresist is the original polymer with the same solubility because the more soluble portion resulting from the exposure is removed. Since the imaged photoresist remains the photoresist (i.e., a polymer), the Applicants submit that the imaged photoresist set forth in the pending claims should be given patentable weight because this recitation refers to the **polymer** that remains as part of the film after it has been imaged.

Regarding the Examiner's combination of Seabaugh and Zhou, the Applicants submit that the combination does not teach or suggest all of the elements of Applicants' pending claims. In view of the teachings on Zhou, it is submitted that one skilled in the art i) would not be led to combine Zhou's photoresist with Seabaugh's electrode, and ii) would *not* achieve the fuel cell recited in Applicants' claims 1 and 49, or the method of claim 48, **even if such a combination were made**.

Seabaugh specifically teaches a composite of two different powders. When applying the composite to a substrate, Seabaugh teaches adding the powder mixture to an ink vehicle to facilitate deposition of the powder mixture on the substrate. After deposition, the coating is annealed.

Zhou, at paragraphs [0065] and [0066] states:

[0065] Now making reference to FIG. 9A, FIG. 9A illustrates a patterned substrate 900 in accordance with an embodiment of the present invention. Initially, a thin layer of photoresist is spin-coated onto a top surface of the glass slide 900. A photo mask with periodic lines (less than 100 micron width) is placed on top of the glass surface coated with the photoresist. After placement of the photo mask over the glass surface, an ultraviolet light source is used to expose the glass. The exposed glass is then developed in chemicals to remove the photoresist materials that are exposed to UV light.

***The developed glass forms a patterned glass substrate with periodic hydrophobic regions which are covered by the photoresist 910 and hydrophilic regions 920 which are free of the photoresist.*** The glass with patterned hydrophobic and hydrophilic regions is submersed into the previously described SWNT/water suspension at room temperature. It should be noted that SWNTs having an aspect ratio preferably of about 10 and a bundle length in a range preferably between about 300 nm and about 1 micron may be used. ***As the water evaporates, SWNTs 930 deposit on the hydrophilic region of the glass slide.***

[0066] In a next operation, the glass slide coated with the SWNTs 930 is washed in a suitable solvent such as acetone, methanol, ethanol, buffered hydrochloric acid or the like. ***During the washing process, the remaining photoresist is removed and the SWNTs 930 remain on the glass surface.*** After removing from the remaining photoresist, the glass slide is heated in either air or vacuum at 200°C to remove the residual solvent to achieve SWNTs 930, as shown with reference to FIG. 9B. The width of the SWNTs 930 can be as small as 0.1 micron and as wide as 1 cm or larger. It should be noted that the SWNTs 930 may have other patterns in addition to that shown with reference to FIG. 9B, such as squares, circles, dots or any other geometry that can be patterned by photolithography. (emphasis added).

Zhou is teaching that a photoresist is used to form a pattern on a substrate for subsequently depositing the nano-objects in a desirable pattern. The exposure of the photoresist layer to UV and a developer creates a pattern in the photoresist layer (and on the glass substrate) because the UV exposed regions are removed (see Fig. 9A, reproduced hereinbelow to facilitate review). However, after deposition of the nano-

objects on the exposed portions of the glass substrate, Zhou teaches that the remaining photoresist layer (i.e., the insoluble portion) is ALSO REMOVED (see paragraph [0066] and Fig. 9B, also reproduced hereinbelow to facilitate review). Zhou does **not** teach generating a patterned film which **includes the insoluble photoresist material**, rather he teaches the use of a photoresist as a photo mask (see paragraph [0065]) for depositing the nano-objects in a desirable pattern.

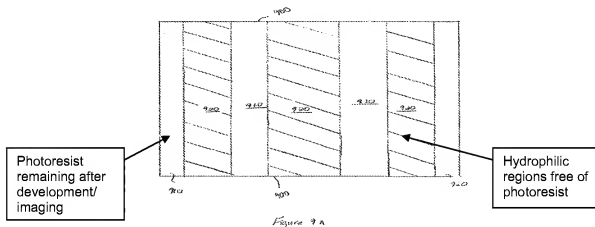


Figure 9A of Zhou

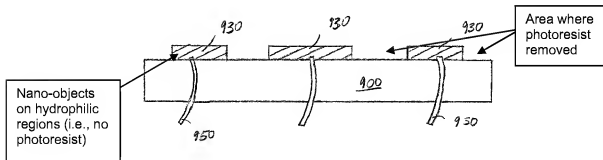


Figure 9B

Figure 9B of Zhou

As shown and discussed in Zhou, the photoresist is essentially a masking layer for subsequent deposition steps, and **all of the photoresist is ultimately removed**.

As such, Applicants submit that one skilled in the art would not be led to replace Seabaugh's ink vehicle with Zhou's photoresist.

Furthermore, it is respectfully submitted that the Examiner's statement (at pages 4-5 of the instant Office Action) that "when the water evaporates, the nano-objects, *or insoluble material* of the photoresist, are present" is incorrect. As set forth above, when the water evaporates, both the nano-objects and the insoluble material are present, but the nano-objects are established "on the hydrophilic region of the glass slide" (i.e., the regions that are **free of the photoresist**, see paragraph [0065]), and thus are next to the hydrophobic regions which are covered with photoresist. Once the remaining photoresist is removed, the structure of Zhou contains nano-objects and NO photoresist.

For at least these reasons, the combination of Seabaugh and Zhou does not teach, suggest, or otherwise render obvious the Applicants' invention as defined in the pending claims, which include a patterned film established on a substrate, the patterned film including insoluble matter of an imaged photoresist having a plurality of nanowires dispersed therein.

Assuming *arguendo* that one skilled in the art was to include Zhou's photoresist with Seabaugh's composite, based on the teachings of Zhou, it is submitted that the photoresist would be removed from the composite, and no nano-objects (other than the particles taught by Seabaugh) would be present in the composite. Furthermore, since Zhou's nano-objects are not present in the photoresist, it is also submitted that if one were to include Zhou's nano-objects with Seabaugh's composite, no photoresist would be present in the resulting composite. As such, any film resulting from the combination of Zhou and Seabaugh would not be the same as Applicants' recited patterned film, at least because the insoluble photoresist matter would not be present in the electrode.

For all the reasons stated above, it is submitted that Applicants' invention as defined in independent claims 1, 48 and 49, and in those claims depending therefrom,

is not anticipated, taught or rendered obvious by Seabaugh, either alone or in combination with Zhou, and patentably defines over the art of record.

Claims 1-3, 6, 12-20, 48, 49 and 68-72 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Huang et al. (U.S. Patent Application Publication No. 2002/0098406) in view of Zhou et al. (U.S. Patent Application Publication No. 2003/0180472). The Examiner states that Huang discloses a solid oxide fuel cell including an electrolyte substrate and an electrode including an inherently patterned paste of nano-sized particles of electrocatalytic noble metals and ceramic ionic conducting particles. The Examiner admits that Huang does not disclose a patterned film including insoluble matter of an imaged photoresist having a plurality of nanowires dispersed therein. The Examiner relies upon the teachings of Zhou to supply this deficiency. The Examiner particularly sets forth that Zhou discloses making a patterned substrate by spin-coating a photo-resist on a substrate, and then submersing the substrate into a solution of nano-objects and water. The Examiner concludes that when the water evaporates, the nano-objects, *or insoluble material of the photoresist*, are present.

Applicants reiterate the arguments set forth herein regarding the term "imaged photoresist", and submit that such term should be given patentable weight.

Huang teaches that his electrode includes a three-dimensional solid phase having an electrocatalytic noble metal phase of noble metal particles and an ion conducting phase of ionic conductor particles. Huang teaches that an electrode paste is formulated, including the particle mixture and a solvent. The paste of Huang is deposited to form a coating, which includes the solvent and the particle mixture.

As shown and discussed herein regarding Zhou, the photoresist is essentially a masking layer for subsequent deposition steps, and **all of the photoresist is ultimately removed**. As such, Applicants submit that one skilled in the art would not be led to replace Huang's solvent with Zhou's photoresist.

Assuming *arguendo* that one skilled in the art was to include Zhou's photoresist with Huang's particle mixture, based on the teachings of Zhou, it is submitted that the

photoresist would be removed from the mixture and no nano-objects (other than the particles taught by Huang) would be present in the resulting film. Furthermore, since Zhou's nano-objects are not present in the photoresist, it is also submitted that if one were to include Zhou's nano-objects with Huang's particle mixture, no photoresist would be present in the resulting composition. As such, any film resulting from the combination of Zhou and Huang would not be the same as Applicants' patterned film, at least because the insoluble photoresist matter would not be present in the electrode.

For all the reasons stated above, it is submitted that Applicants' invention as defined in independent claims 1, 48 and 49, and in those claims depending ultimately therefrom, is not anticipated, taught or rendered obvious by Huang, either alone or in combination with Zhou, and patentably defines over the art of record.

In summary, claims 1-20, 48, 49 and 68-72 remain in the application. It is submitted that, through this Amendment, Applicants' invention as set forth in these claims is now in a condition suitable for allowance.

Further and favorable consideration is requested. If the Examiner believes it would expedite prosecution of the above-identified application, the Examiner is cordially invited to contact Applicants' Attorney at the below-listed telephone number.

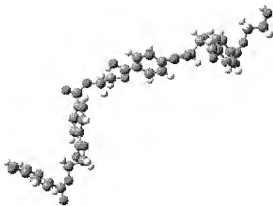
Respectfully submitted,

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JCD/JRK



# Chem421

## Introduction to Polymer Chemistry

Department of Chemistry  
University of Rochester

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### Course Description


Introduction to Polymer Chemistry provides an overview of the chemistry and physics of polymers. The structures and synthetic mechanisms of most commercially important polymers are discussed, including step and chain polymerization reactions, as well as polymer modification chemistry. Theories of the physical properties of polymers both in solution and in the solid state are covered. Characterization topics include molecular weight averages, thermal transitions, and mechanical properties.

This course is intended for graduate students in Chemistry, Chemical Engineering, or Materials Science.



Advanced undergraduate students can also enroll. Prerequisites: one year undergraduate courses in both Organic and Physical Chemistry.

The course is taught by two research scientists from local industry, who are adjunct professors in the Department of Chemistry.

 The content of Chem 421 is being presented as a course in the Chemical Engineering Department during Spring 2003. (CHE 286/486) You are welcome to browse this site, but more up to date information can be obtained on the course site in Chemical Engineering (CHE 286/486). (Link not yet active)

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 The successor course to Chem 421 is  [Chem424 Synthetic Polymer Chemistry Home Page](#)

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 [U of R Chemistry Department Home Page](#)

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Last updated 18 December 2002

# Chem 421: Introduction to Polymer Chemistry

## The Chemistry of Photoresists

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### General Principals

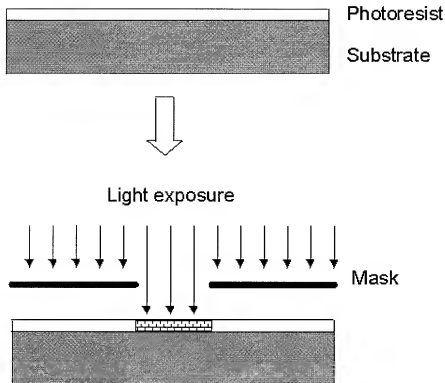
Photoresists have enabled the modern electronic revolution. The patterns of conductors on circuit boards and the tiny transistors on microchips are "printed" using photoresists. The technology of photoresists has been refined to the point where many millions of micron-sized devices can be fabricated simultaneously and reliably on silicon substrates. Research on yet smaller (and therefore more dense and efficient) circuitry continues apace today.

The story of photoresists is largely one of *polymer modification chemistry*. All photoresists are polymeric coatings that are designed to change properties upon exposure to light. Then, either the exposed or unexposed regions of the coating can be selectively removed to reveal the substrate beneath. The second role of the photoresist is to "resist" the actual circuit formation step, i.e. etching, ion implantation, metal deposition, etc., thereby protecting the substrate beneath where required. In most cases, the process is repeated many times to produce the final, complicated pattern of circuitry.

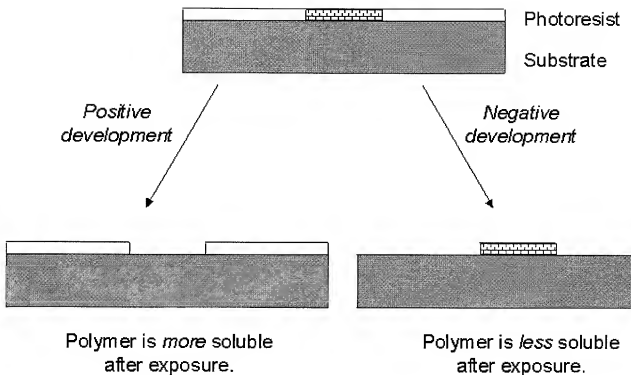
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### Photoresist Processing

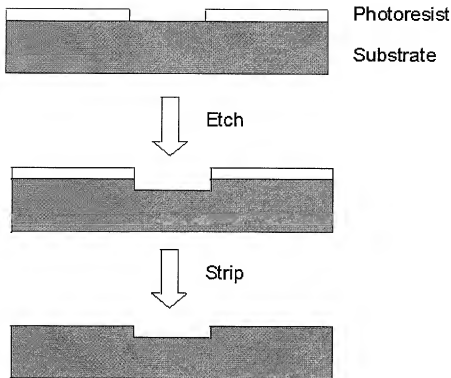
The process begins by covering the whole substrate surface with a thin layer (ca. 1 micron) photoresist material, usually by *spin-coating*. The coating is then selectively irradiated with light (usually UV) through a stencil, or *mask*, that is designed to allow light to fall only on desired places.



The light causes a chemical change in the exposed region. Depending on the system, it is possible to wash away either the exposed or unexposed regions selectively, using the appropriate fluid, called the *developer*. When the exposed region is removed by the developer (i.e., exposure makes the photoresist more soluble), the process is called *positive tone*, and when the developer leaves the irradiated region behind (i.e., irradiation makes the photoresist less soluble), the process is called *negative tone*.



In the final step, some kind of process is applied to the revealed substrate. In the example shown below, a chemical treatment etches away some of the substrate, while the photoresist protects the other regions. (Alternatively, metal deposition, ion implantation, or other processes can be carried out.) Finally, an appropriate reagent removes (*strips*) the remaining photoresist, and the substrate is ready for the whole process to be repeated for the next stage of circuit fabrication.

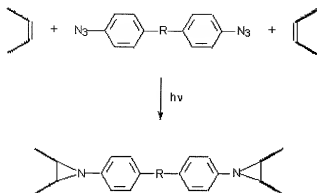


## The Chemistry of Photoresists

There are numerous polymer systems that have been applied to photoresist technology. Below are presented a few selected examples among many. Photoresists continue to be an active area of research for polymer chemists, as devices of ever smaller sizes are pursued.

### Bisazide crosslinking

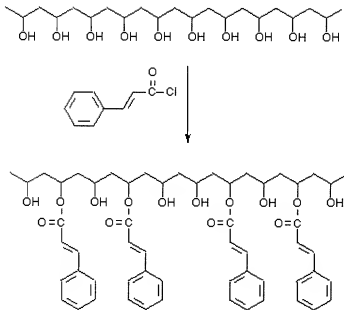
The earliest photoresists were based on the photocrosslinking of "cyclized rubber" using an additive that contained two azide groups. (Cyclized rubber is obtained by acid treatment of poly(*cis*-isoprene), a process which leads to some ring formation in the polymer, and stiffens it, thereby raising its  $T_g$ .) When the bis-azide is photolyzed, it extrudes nitrogen and produces two very reactive nitrene moieties. The nitrenes can form bonds with the cyclized rubber in a variety of ways, the most common of which is aziridine ring formation, as shown.



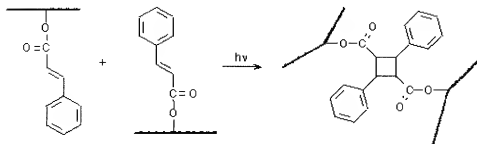
Naturally, these reactions lead to crosslinking of the polymer, and it becomes less soluble, ready for negative development.

### Poly(vinyl cinnamate)

Another interesting negative tone photoresist is poly(vinyl cinnamate). This polymer is synthesized by the partial esterification of poly(vinyl alcohol), which itself is made by a polymer modification reaction (hydrolysis of poly(vinyl acetate)).



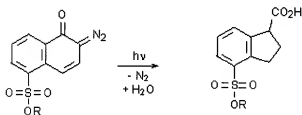
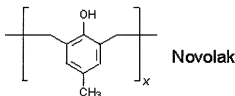
The cinnamate groups undergo [2+2] cycloaddition when irradiated, leading to a crosslinked polymer suitable as a negative tone photoresist.



### Novolaks

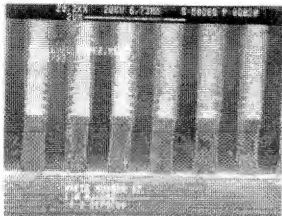
Novolaks are phenol-formaldehyde type polymers, generally synthesized using cresol rather than phenol, with the polycondensation reaction halted before the polymer becomes crosslinked. Being phenols, these polymers are soluble in aqueous base, although the rate of dissolution is quite slow. However, in the presence of suitable additives, the dissolution process can be greatly enhanced. The additives can be produced photochemically, leading to a useful photoresist system. In fact, Novolaks have been the "workhorse" photoresists of the modern microelectronic revolution.

The photoresist consists of Novolak polymer, with a small amount of diazonaphthaquinone dissolved in it. When irradiated, the diazonaphthaquinone undergoes the *photochemical Wolff rearrangement*, which eventually produces a carboxylic acid.



### Diazonaphthaquinone additive

Of course, the carboxylic acid (produced by irradiation) is even more soluble in base than the Novolak itself. Its presence increases the rate of dissolution of the coating by *orders of magnitude*. Therefore the unirradiated regions are effectively insoluble, leading to a *positive tone photoresist*. The exact reason for the increased dissolution rate is not yet understood, and remains a matter of contention and research. Nevertheless, this system works well, and can produce very intricate features, as shown below.

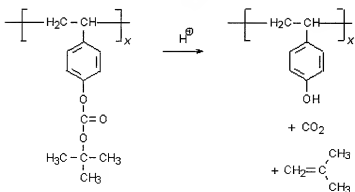


### Chemically Amplified Photoresists

While the Novolak photoresists provide excellent performance, there is always room for improvement. One aspect that was addressed through clever polymer modification chemistry was the amount of light required to produce sufficient enough chemical change for development. That is, if the amount of light exposure, or *dosage*, required could be lessened, the whole process could be carried out faster.

Collaborative work between IBM (especially C. Grant Winson, now at Univ. of Texas Austin) and Prof. Jean Frechet (then at Univ. Ottawa, now at Berkeley) resulted in the invention of the concept of *chemically amplified photoresists*. In this system, exposure to light creates a *catalyst* for another chemical reaction. The second chemical reaction is responsible for the change in solubility needed for development. The essence of chemically amplified photoresists is that one photon can lead to many secondary reactions, therefore the available light is used very efficiently. (Quantum yield is much greater than 1.)

The most well known system of this kind is based on *t*-Boc-styrene polymer. Simply put, this polymer contains phenolic groups protected with *t*-Boc groups. In the presence of acid catalyst, the protecting groups decompose to carbon dioxide and isobutylene, both gasses that leave the coating. The deprotection reveals phenolic moieties, which are soluble in aqueous base, therefore this material can function as a *negative tone photoresist*.



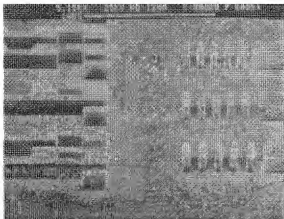
Interestingly, poly(*t*-Boc styrene) can also work as a *positive tone photoresist* by using another developing solvent. The unmodified, original polymer is soluble in nonpolar solvents, for example anisole, and can be selectively washed away to leave behind the more polar modified polymer, which is



insoluble in anisole. However, the negative mode is more often used because of the low toxicity of the aqueous base developer.

As with Novolak, the key ingredient is the so-called *photochemical acid generator*. These compounds were developed by James Crivello (then with GE, now at RPI), and usually take the form of iodonium ( $R_2I^+ X^-$ ) or sulfonium ( $R_3S^+ X^-$ ) salts. These compounds decompose upon light exposure to provide a complicated mixture of products, chief among which is the acid HX. This acid then catalyzes the deprotection reaction of many *t*-Boc groups.


Very fine features can be fabricated using this system, with very little light required to do the job.



### Future Directions

- Industry is moving to ever shorter irradiation wavelengths (193 nm and then even lower) to get finer features.
- Aromatic-containing polymers are opaque at these short wavelengths, so new polymers and systems are required.
- Chemical amplification is essential to success.
- Environmental issues are increasingly important.
- Lots of research remains to be done (IBM, Bell Labs, Arch Corp, and many other labs)

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